

Why Does it seem like Charleston Always Floods When it Rains?

THE CHALLENGES OF DRAINING A CITY THAT IS LOW, FLAT, AND
NEXT TO THE OCEAN



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Introduction

The Greater Charleston area has always had a long history of drainage and flooding problems since its founding more than 300 years ago. This is primarily because it is difficult to drain a city that is surrounded by water, next to the ocean, and only a few feet above mean sea level.

Various drainage techniques have been implemented since the 1800s with varying degrees of success.

Despite the great advances in our understanding of urban stormwater drainage and progress in technology, we are still unable to overcome some very basic challenges of stormwater hydraulics and Hydrology.

- Hydrology: How rain accumulates and flows on the ground surface.
- Hydraulics: how water flows into inlets and through pipes.

Definitions

- Stormwater – Rain that does not soak into the ground (runoff).
- Design Storm - A hypothetical discrete rainstorm characterized by a specific duration, temporal distribution, rainfall intensity, return frequency, and total depth of rainfall.
- Impervious Surfaces – Hard surfaces that do not allow rain to soak in such as concrete, asphalt, buildings, etc.
- Flow rate (Q) – How much water flows during a certain period of time; often measured in cubic feet per second (cfs).
- Outfall– The location where the stormwater exits the system to a water body (river, marsh, harbor, etc.).

- Head – The elevation (height) difference between two water surfaces.
 - This can also be thought of in terms of how much more energy the water at the higher elevation has compared to the water at the lower elevation.
 - The greater the difference in elevation (larger head) the more energy (and therefore speed) the water has to move through the stormwater system.
 - This energy can be “felt” by swimming to the bottom of a pool and feeling the pressure squeeze your head.

If all rain event were slow and gentle, we would have no need for our “modern” stormwater systems and flooding would not be a problem.

The assumptions that most people make about rain events are:

- Rain falls at the same rate for the whole storm
- Rain is the same amount over the entire area
- Rain falls at the same time over the entire area.

All of these assumptions are false.

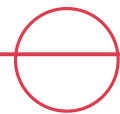
Just like how all people are different, ALL RAIN STORMS ARE DIFFERENT. Rain never falls in the same way.



What Happens When the Rain Falls?

What Happens When the Rain Falls?

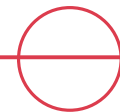
Step 1



Rain falls to the ground and runs off impervious surfaces.

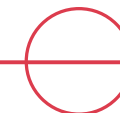
The stormwater flows across the land, over parking lots, through swales, down ditches, along gutters, and eventually makes its way to storm drains.

Step 2



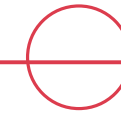
The stormwater flows into the storm grate and is collected in the catch basin.

Step 3



The stormwater flows from the catch basin into the system of stormwater pipes.

Step 4



The stormwater flows through the conveyance system to the outfall.

Each of these four steps requires a finite amount of time to accomplish so no matter how a system is designed, draining an area of land can never be instantaneous.

Each step also offers an opportunity for a bottleneck to develop, which would slow down the entire process.

Drainage Challenges in the Lowcountry

The challenges we face in draining the city during and after a storm are both natural and man-made in origin.

This variance in origin makes creating a solution to the flooding that much more complicated.

Natural



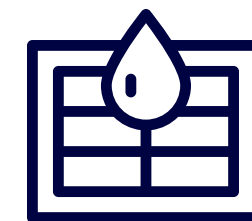
Tide Cycle

Intensity and Duration of Storms



Terrain

Man-made



Inlets

System Size



Trash

Impervious Coverage



Challenge #1:

The Changing Tide Cycle

Head – The elevation (height) difference between two water surfaces.

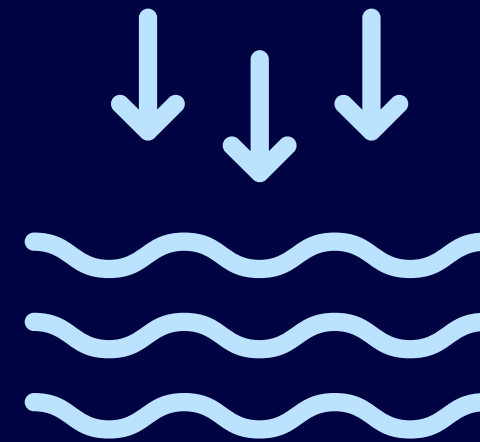
Also known as how much more energy water at a higher elevation has compared to the water at a lower elevation.

The greater the difference in elevation (larger head) the more energy (and therefore speed) the water has to move through the stormwater system.

Tide Cycle Facts

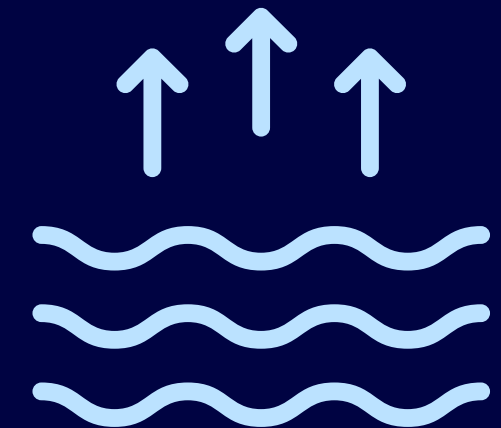
- The difference between high and low tide can be 7 feet or more
- Rain events that occur within two hours of high tide will drain much slower than a standard rain event.
- The tide cycle is approximately 12 hours and the most flood-prone time is 2 hours before and 2 hours after high tide.
- As such, there is a 1-in-3 chance that any rain storm will be adversely affected by high tide.

It is important to remember that most of the outfalls for the city drain into major water bodies that are influenced by the changing tide.



At low tide there is a greater head difference between the surface where the stormwater has collected and the surface of the water body. The larger head will allow the water to flow faster throughout the system due to the greater potential energy.

At high tide there is a much smaller head difference. The water does not have nearly as much potential energy to push its way through the system and therefore drains much slower which may lead to ponding.



Challenge #2:

Storm Intensity and Duration



Key Terms

- Duration is the length of time it rains.
- Intensity is the rate at which the rain falls and is often measured in inches per hour. Dividing the total rainfall from an event by the time span of the event, you can calculate the average intensity of the storm.

If either intensity or duration is considerably large, there is generally no problem.

However, a larger intensity of rain over a longer duration would result in significant amounts of stormwater to be collected.

Example

- Charleston could get a 15 minute cloud-burst, at 2 inches per hour, that only amounts to a 1/2 inch of rainfall. Or it can rain for 12 hours, but the 2 inches that fell is easily absorbed into the ground or slowly runs off and is collected by the stormwater system.
- However, if we were to get the same 2 inches of rain in a shorter amount of time like 15 minutes. There would be significant amounts of stormwater to be collected.

Challenge #2: Storm Intensity and Duration

Important Points to Remember

- It takes time for the stormwater to get to, into, and through the drainage system.
- A rain event that overwhelms any of the four steps mentioned previously will cause flooding.
- A storm that has a duration of several hours or a series of smaller storms may start to drain well naturally, but as the ground becomes more saturated, more water will begin to run off into the storm drains.



Challenge #2: Storm Intensity and Duration

Example

- Picture a partially clogged sink.
- If you turn the water on slowly, the sink may have no problem clearing itself.
- If you turn on the water a little more, the sink may fill up, reach and maintain a certain level, and then continue to drain the water without filling again.
- When the water is turned on full blast, the system is overwhelmed and the sink fills up.
- Once the water is turned off, the basin continues to drain, but still at a slower rate.

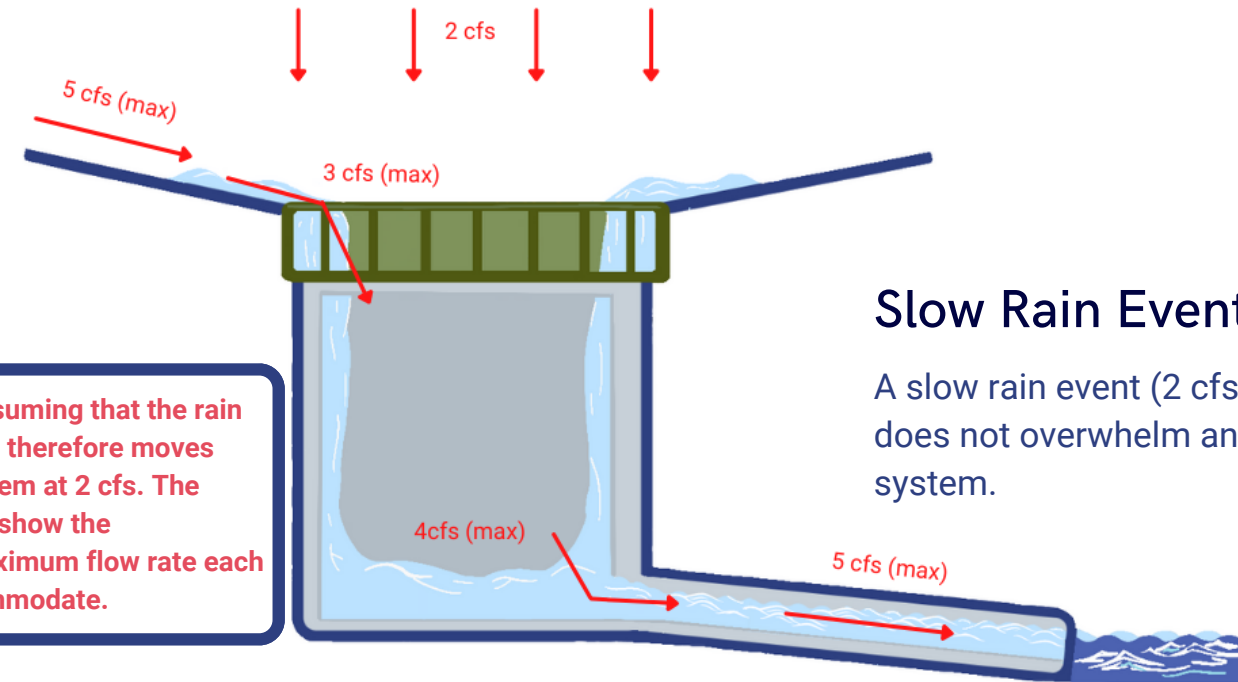
In this instance the water faucet is the rain fall and the sink is our stormwater system.

- The stormwater collection system in downtown and in other parts of the city can comfortably collect and accommodate slow to moderate storms, but can also become overburdened by more intense storms.

Challenge #2:

Storm Intensity and Duration

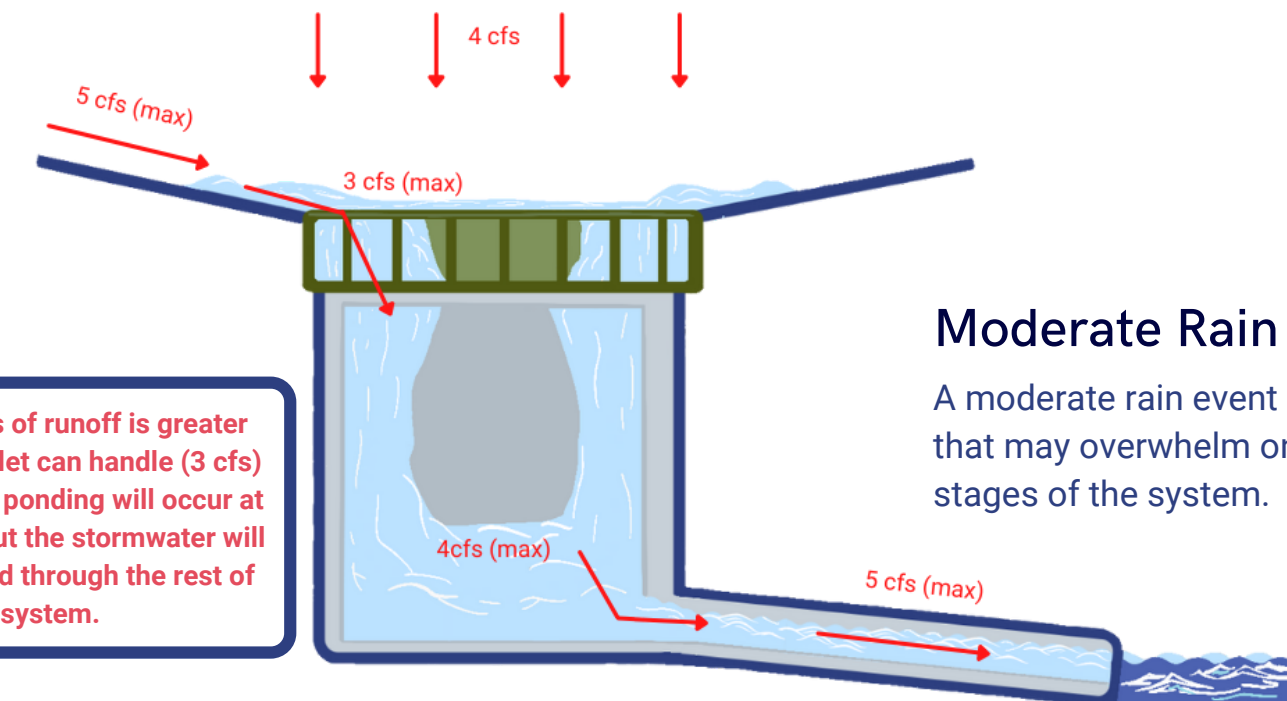
The amount of water that flows during a certain period of time is known as Flow Rate, and is often measured in cubic feet per second (cfs). This concept is illustrated in the diagrams below.



Slow Rain Event

A slow rain event (2 cfs runoff) that does not overwhelm any stage of the system.

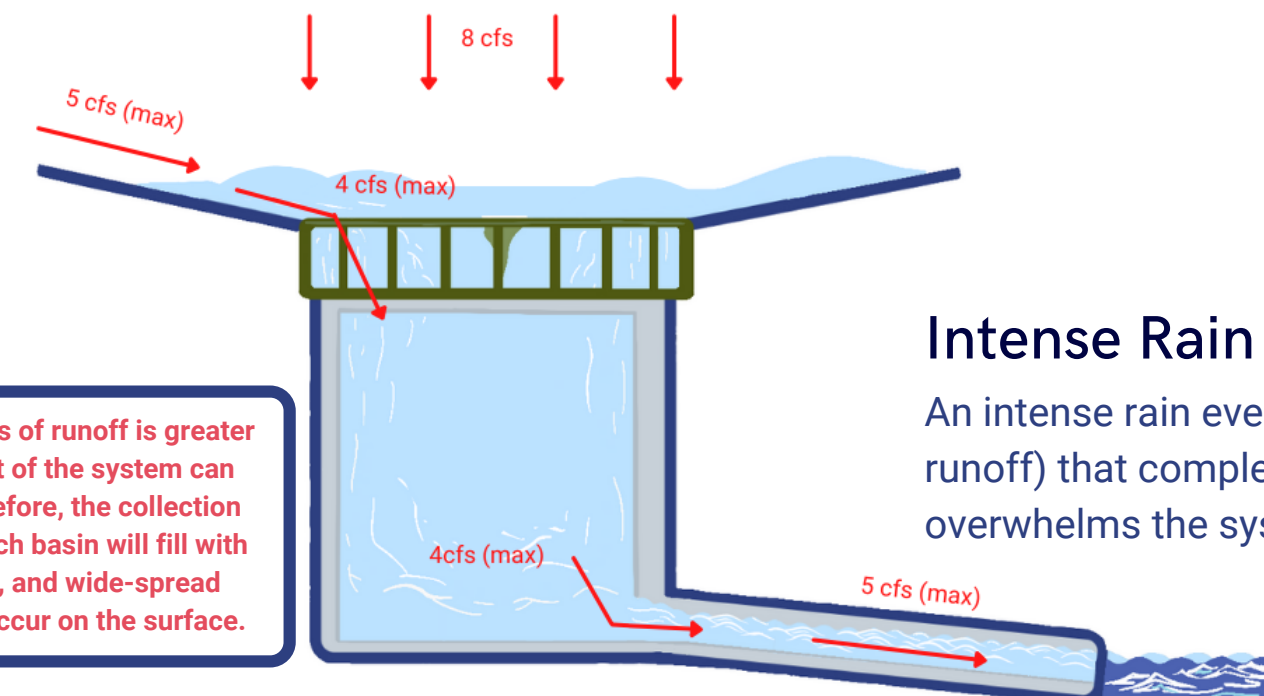
Note: We are assuming that the rain falls at 2 cfs and therefore moves through the system at 2 cfs. The other flow rates show the hypothetical maximum flow rate each stage can accommodate.



Moderate Rain Event

A moderate rain event (4 cfs runoff) that may overwhelm one or more stages of the system.

Note: The 4 cfs of runoff is greater than the grate inlet can handle (3 cfs) max. Therefore, ponding will occur at the grate inlet but the stormwater will pass unhindered through the rest of the system.



Intense Rain Event

An intense rain event (8 cfs runoff) that completely overwhelms the system

Note: The 8 cfs of runoff is greater than any part of the system can handle. Therefore, the collection pipes and catch basin will fill with stormwater, and wide-spread ponding will occur on the surface.

Challenge #3:

Collection System Size



While it is easy to design an unclogged drain to accommodate the flow from a faucet. It would be impractical to design the drainage system to accommodate the largest possible rainfall. To do so with our drainage system would require enormous drains and pipes that would remain unused for the vast majority of time, increasing the cost of construction significantly.

For practicality and cost-effectiveness, new stormwater collection systems have been designed to accommodate the runoff from a rain event of a certain intensity and duration, also known as the design storm.

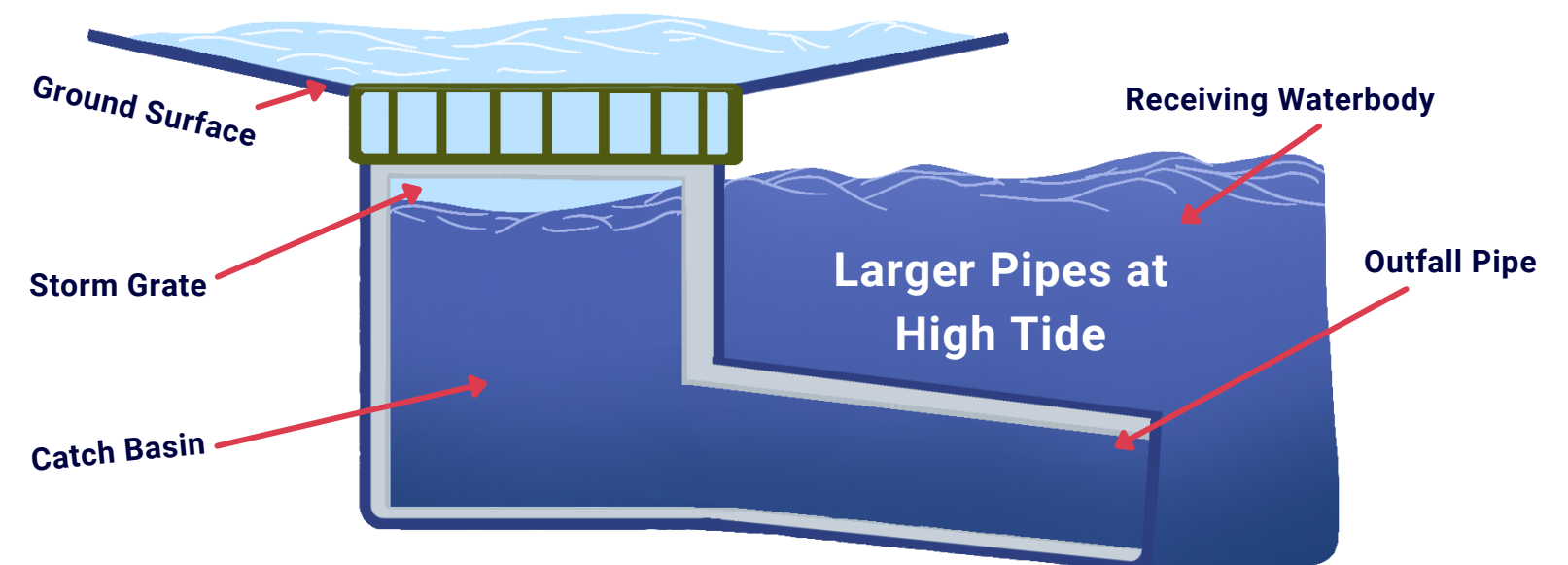
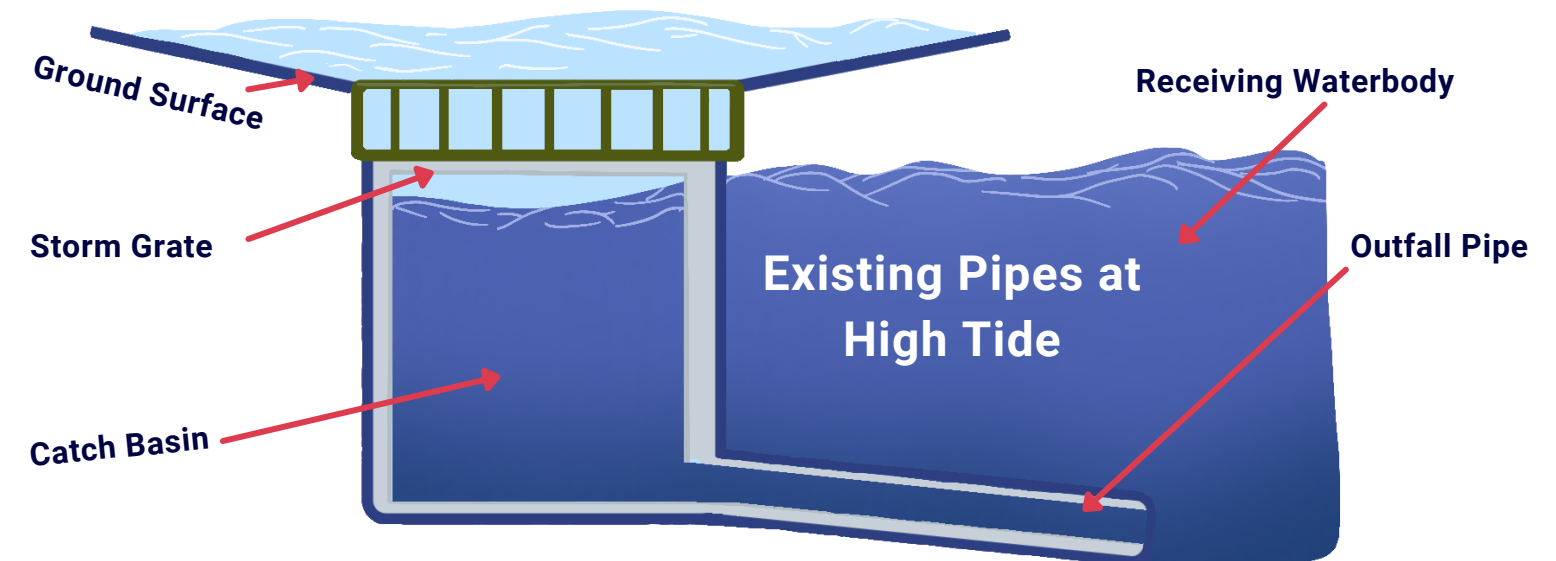
Any rain event larger than the design storm may cause the system to back up.

However, this design method is less effective when used in a city such as Charleston, where the stormwater collection and conveyance system was a 150-year afterthought, as many of the pipes are not adequately sized.

Challenge #3: Collection System Size

An often-suggested solution to undersized pipes would be to simply install larger ones.

While this would be an "easy" fix there are **two** significant challenges that limit its implementation.



1 limited space in which we have to install stormwater lines.

- Not only do we need to increase their size, but we need to ensure that the lines flow properly under the influence of gravity.
- The streets are the only practical place to put stormwater lines, but many are quite narrow and already filled with other utilities such as water, sewer, gas, electric, telephone, and cable.
- Space to construct new or larger stormwater pipes is quite limited.



2 Larger lines must be placed deeper in the ground

- If installed at the same elevation as the smaller pipes, the larger pipes might stick out of the ground or possibly not have the recommended amount of cover.
- Because much of the collection system is already full of water at high tide, placing the lines deeper in the ground will just cause them to fill up sooner with tidal water and will not provide any additional benefits.

Challenge #4:

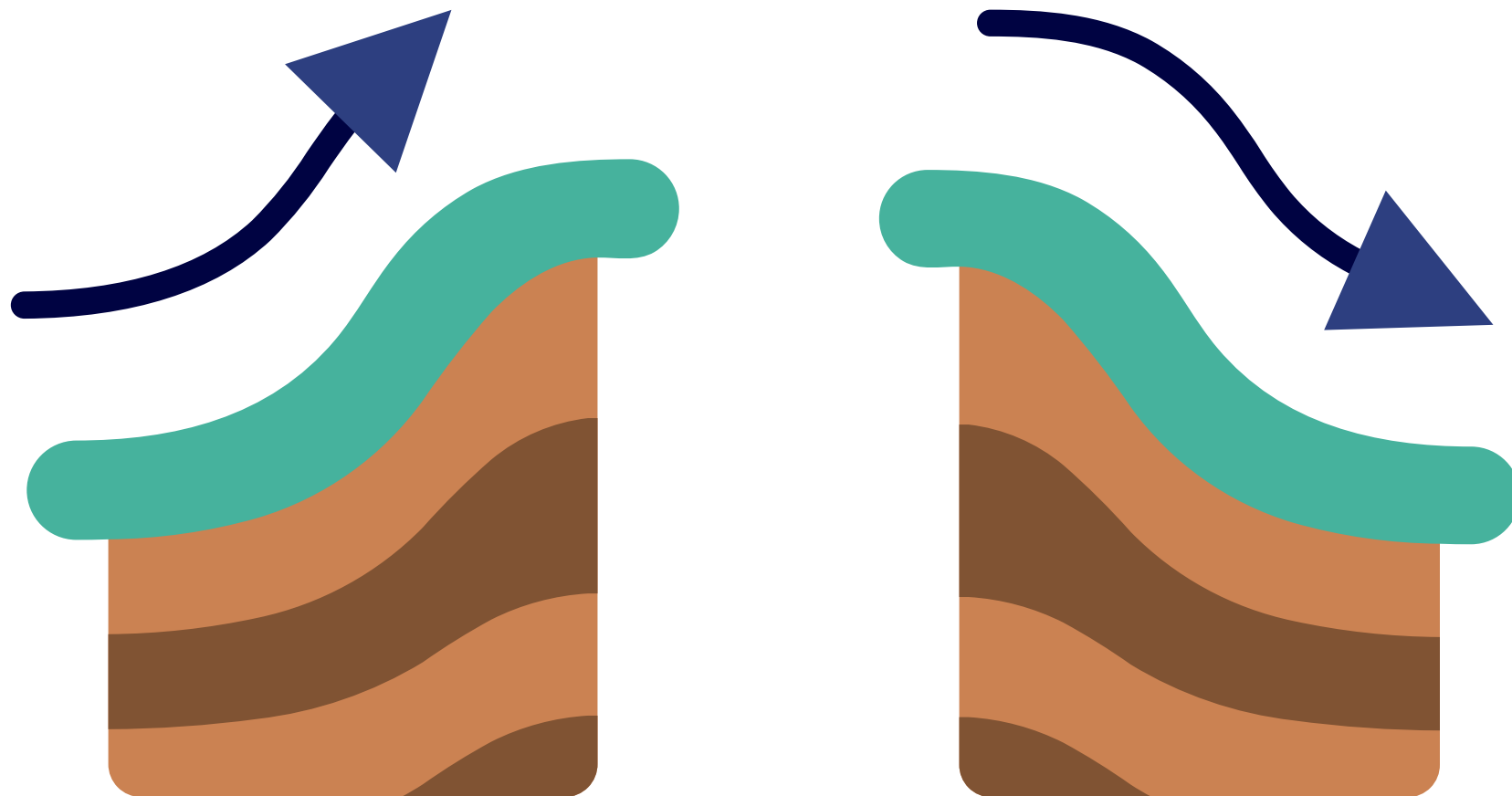
Variance in Terrain

Gravity moves stormwater across the land and to stormwater grates and inlets.

If we were in the Piedmont or the Upstate where there are hills and mountains with steeper slopes, terrain would be much less of a factor.

Unfortunately, the Lowcountry has either very gentle slopes or completely flat land.

The flatter the terrain, the slower the water will move, and the more time it will take drain an area of land.



Challenge #4: Variance in Terrain

1.) How water flows over land with varying terrain.

Step one

Grab the nearest large piece of plywood and a 2-by-4

Step two

Place the 2-by-4 on its narrow side. Place one end of the plywood on the 2-by-4, and place the other end on the ground

Step three

Pour a cup of water on the raised end of the plywood and note the speed of the water as it runs down.

Step four

Now, place the 2-by-4 on its flat side, again with one end of the plywood on the 2-by-4 and the other end on the ground.

Step five

Pour another cup of water on the plywood and note that it flows a little slower down to the ground.

Challenge #4: Variance in Terrain

2.) How water flows over land in the Lowcountry.

Step one

Grab the
nearest large
piece of
plywood and a
2-by-4

Step two

Place the
plywood flat
on the
ground.

Step three

Pour a third
cup of water
in the middle
of the
plywood and
note how the
water forms a
small pond in
the center of
the wood.

Challenge #5:

Inlets



The number and size of inlets will affect how quickly an area can drain.

With more inlets, there are more ways for the stormwater to enter the collection system.

With the increase in the number of inlets, the stormwater has less overland distance to travel, thus reducing the travel time and the time it takes to drain an area.

Since the stormwater system is often considered an after thought in most urban areas, the location and number of inlets is limited by multiple factors, including, but not limited to, location of existing structures and utilities



Large inlets are not effective if the system to which they drain is unable to accommodate the flow from them (see challenge #3)

There is, however, a limit to the size of the openings that are allowable for inlets since large openings are a safety hazard.

With larger inlet openings, there is usually more surface area and the inlet can accept more stormwater.

Challenge #6:

Trash



Arguably, the biggest detriment to the surface collection system is trash and debris.

Common items ranging from newspapers, wrappers, and plastic grocery bags to pine straw, bark mulch, and live oak leaves quickly reduce the amount of water that can flow into the system and cause flooding.

During nearly every rain event, the city receives scores of calls to remove trash and debris from storm drains.

Since the city has a finite amount of people and resources, many of whom are attending to critical roads and intersections to maintain traffic flow for emergency vehicles, we cannot be everywhere at once.

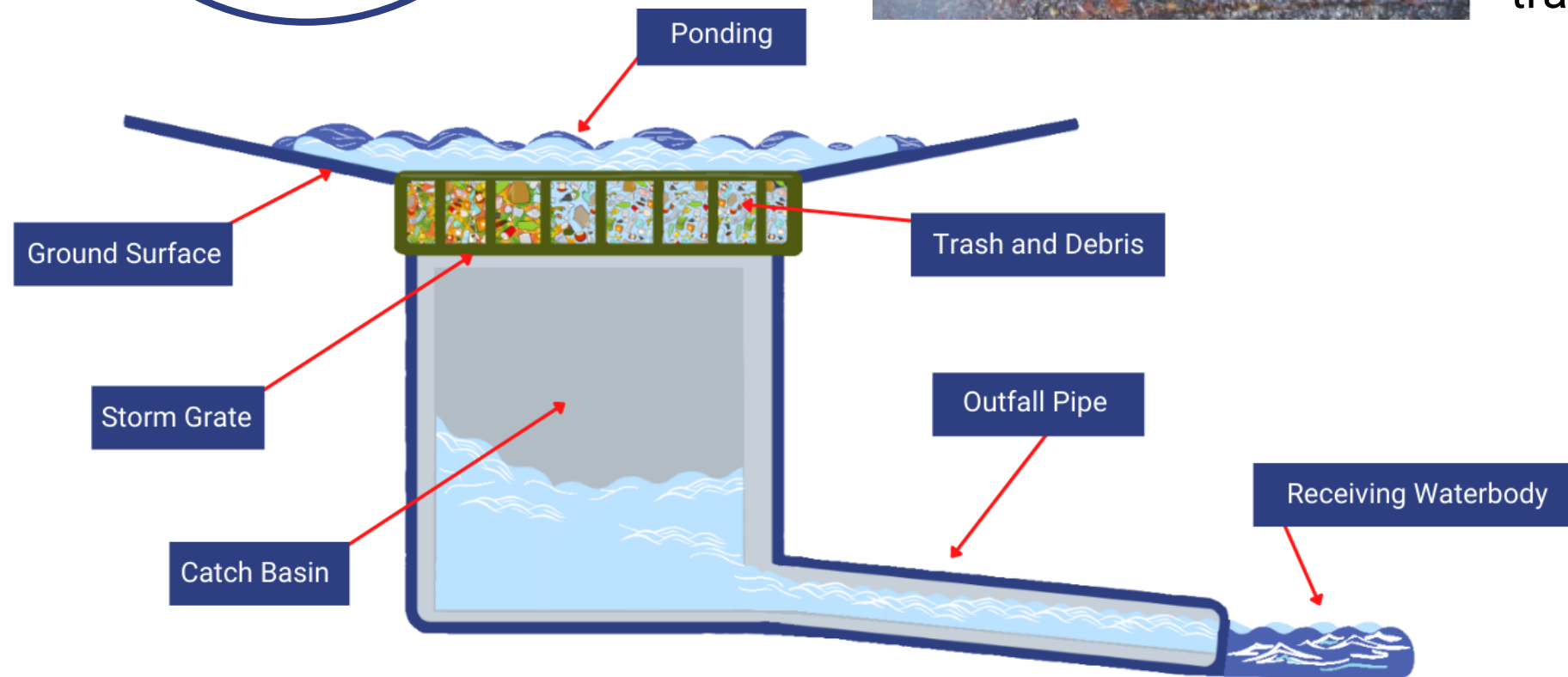
Many of these calls are preventable as residents can clean off storm drains before the storm or after dangerous weather conditions have passed.

Challenge #6: Trash

“Residents can help themselves by helping us.”



Many residents may not realize that it is the responsibility of the property owner and/or renter to remove and properly dispose of all trash and debris from their property.



Trash and debris caught on and in the storm grate causes ponding on the surface.

Trash and debris that gets caught on and in storm grates causes ponding to form on our ground surfaces, which leads to flooding.

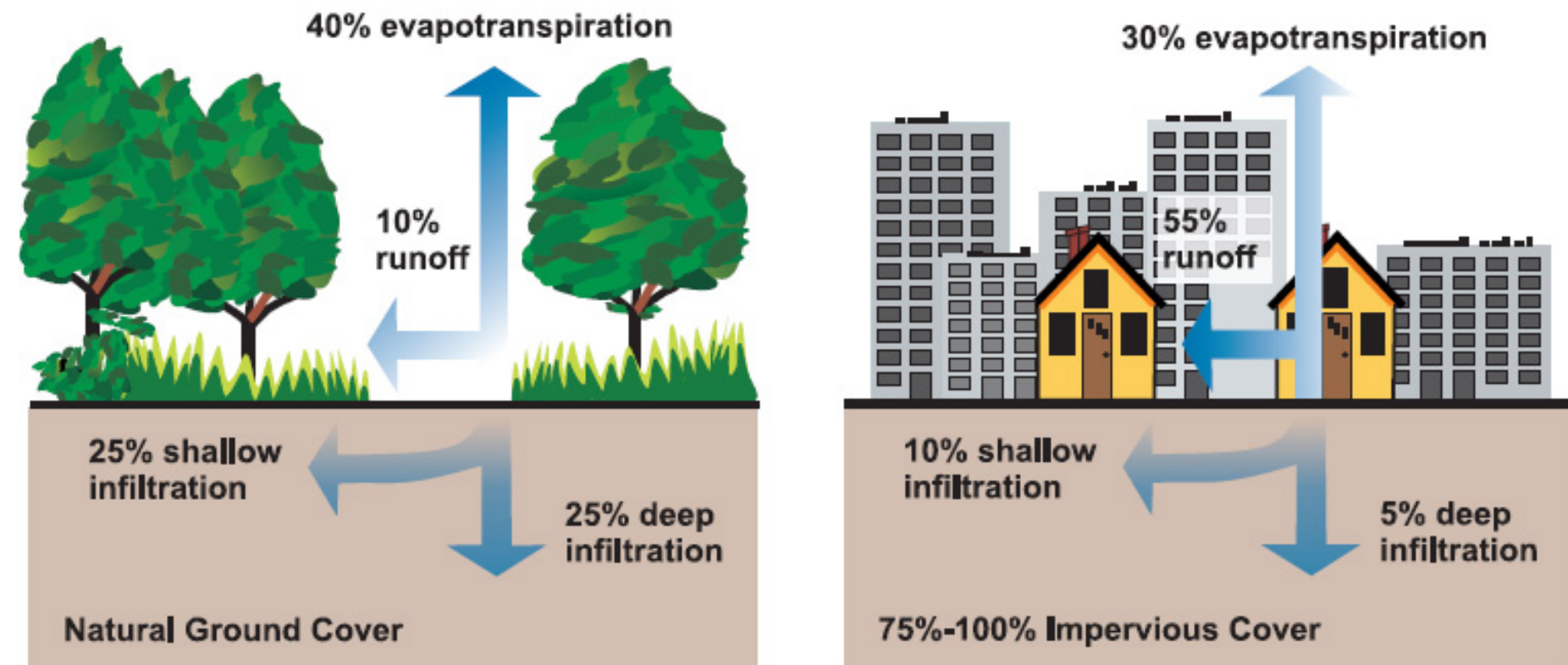


Charleston City Code, Section 28-7 states it is unlawful to dump, deposit, or otherwise cause any material to be placed within the stormwater system.

Charleston City Code, Section 14-5 also states that: The owner or occupant is required to keep the property free of litter and debris. The property must be kept clean and free of debris up to and including the sidewalk, curb, and gutter. It is unlawful to push trash or debris into the street.

Challenge #7:

Impervious Cover



Much of the peninsula of Charleston has been “built-out” , meaning that most of the land has been covered with hard surfaces that shed rain water.

When buildings, roads, sidewalks, driveways, and parking lots are constructed on land that once contained grass, brush, trees, or even bare soil, the rain that falls on these hard surfaces cannot soak into the ground.

Instead, the water that runs off these impervious surfaces must find its way across the land, into the gutters, and down the storm drains.

The Stormwater volume is greatly increased since much of the rain now runs off instead of soaking into the ground.

Smooth, hard surfaces like asphalt and concrete increase the speed of the stormwater as it makes its way to the collection system.

Combine these two factors, and we now have greater volumes of stormwater rushing more rapidly to drains that may be clogged with trash and full of seawater at high tide causing flooding.

What is the City doing about the Flooding?

#1
Overland
Flow

#2
Flowing into the
Storm Grate

#3
Flowing into the
Conveyance
System

#4
Flowing through
the Conveyance
System

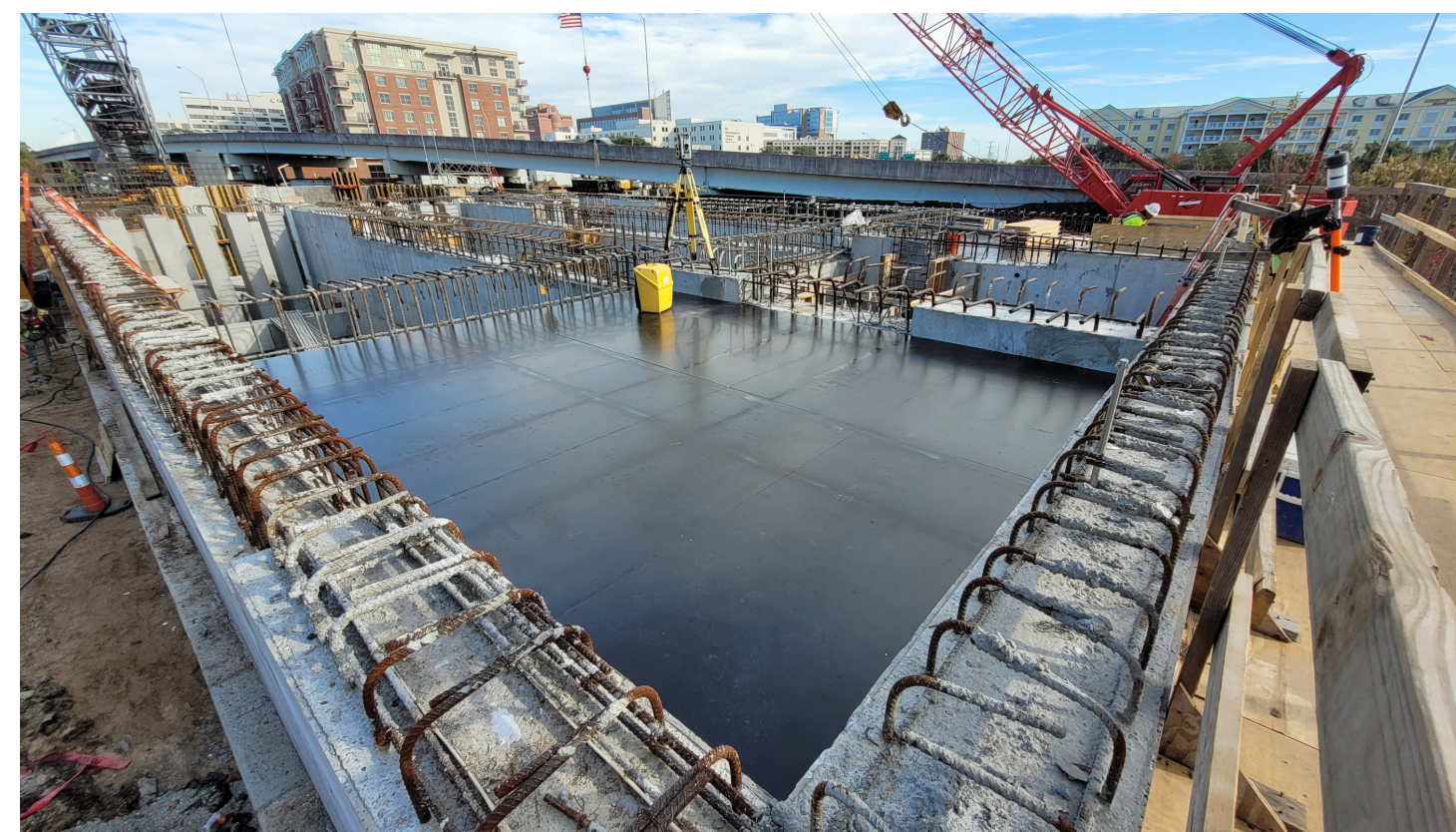
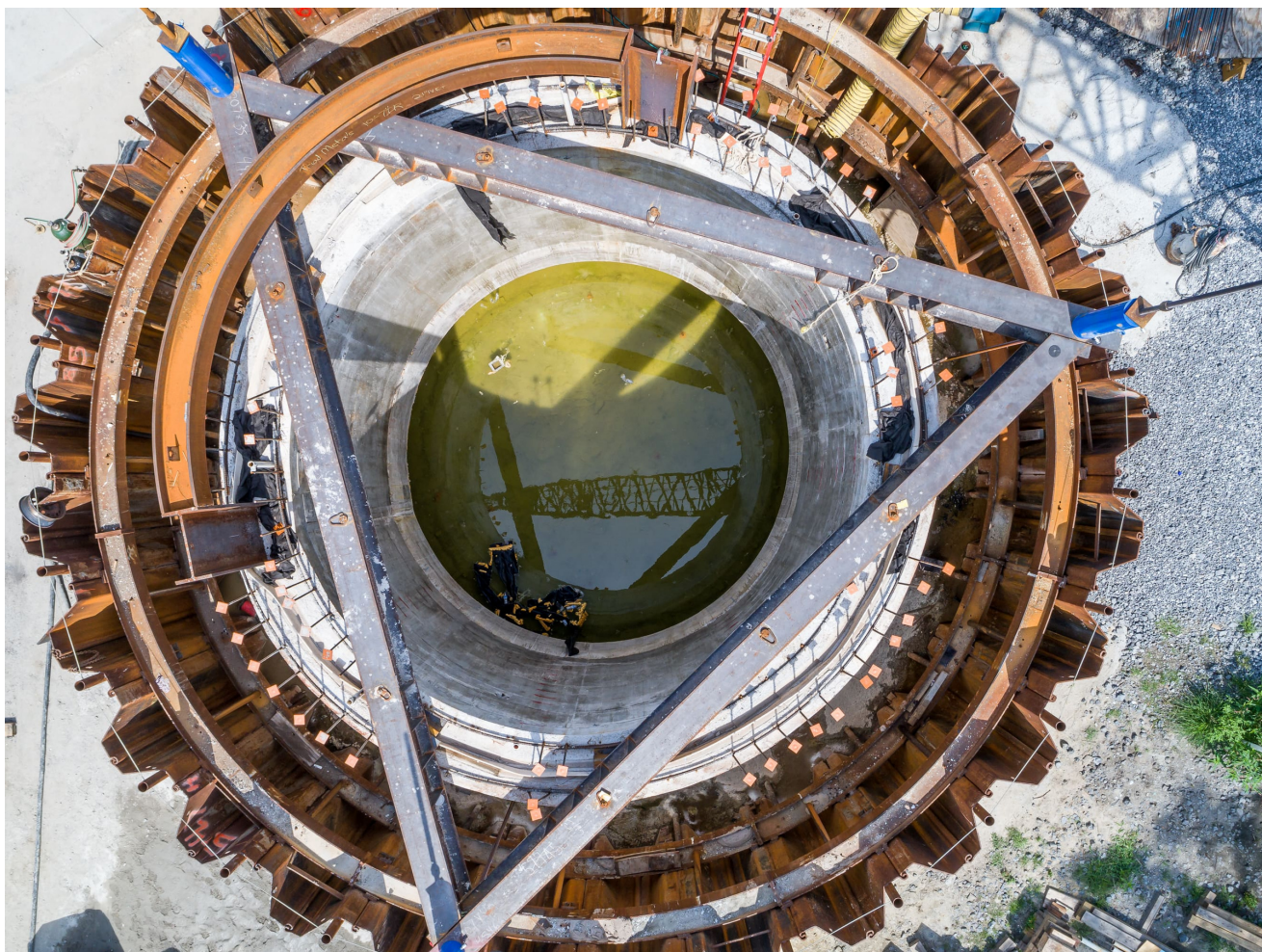
Keeping in mind, there
are four potential
bottlenecks that may
slow the stormwater
progression to the
pumps

What is the City doing about the flooding?

The drainage problems the city faces are long-standing and the solutions are often more complex than many people realize.

The more complex the solution, the longer it takes to develop and implement, and the more it costs.

The city is working toward resolving all drainage problems in the most effective and cost-efficient way to ensure proper stewardship of citizen resources.



One solution for the flooding is to build pump stations for the most flood-prone areas.

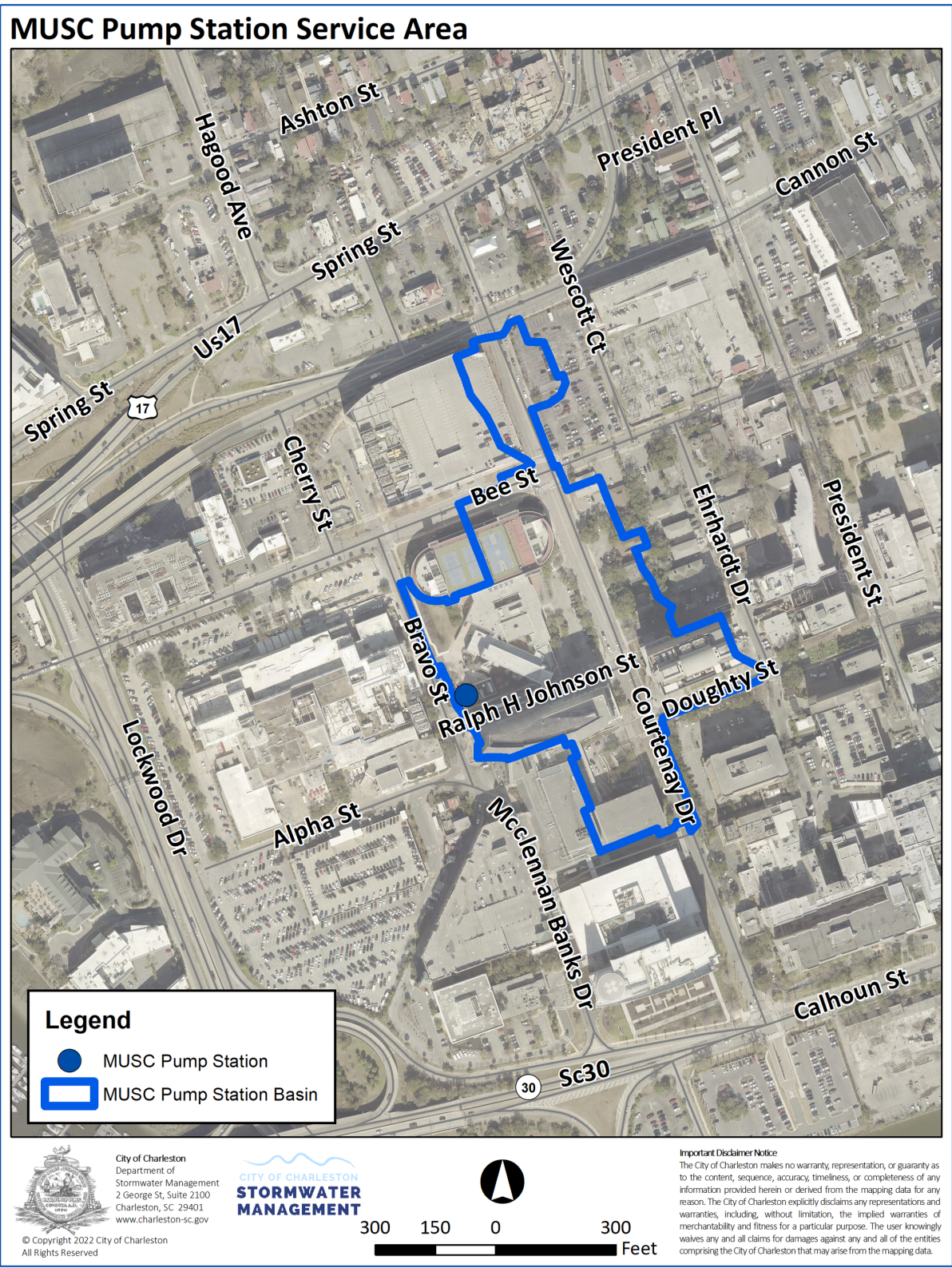
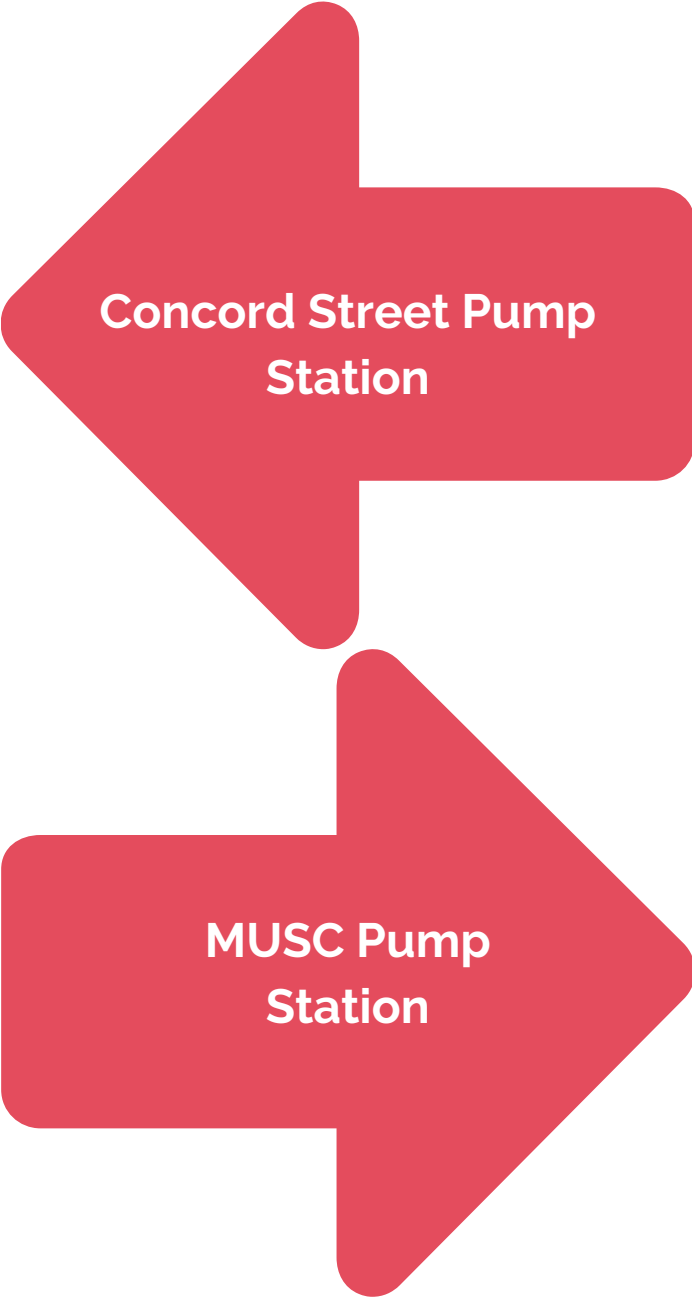
The pump stations will decrease the length of time it takes for the water of a flooded area to drain by providing the necessary energy (head) to the water, even at high tide.

Once the stormwater reaches the pump station under non-tropical system conditions (i.e. no storm surge), the pumps will be able to push it into the water bodies without needing to wait until high tide passes.

However, there are limitations to how much flooding the pump stations will be able to alleviate as the stations are unable to increase the speed with which the water moves throughout the collection system.

Existing Pump Stations

As a way to mitigate the previously mentioned challenges, the city has already establish two pump stations on the peninsula.
They are the Concord Street Pump Station and the MUSC Pump Station.
Their service areas are represented in the images below.





But how do
these pump
stations work?

The pump station then
pumps the stormwater
into either the Cooper
River or the Ashley
River.

First the stormwater is
collected on the surface
and drops through a few
dozen small diameter
shafts to the deep tunnel,
and then flows through the
tunnel to the pump station.



Once completed, this project will move water from the surface through a network of surface collection pipes, vertical drop shafts, and deep tunnels to a pump station where it will ultimately end up in the Ashley River.

[illegible]

The U.S. 17 Spring/Fishburne Drainage Improvement Project

PHASES 1-3

Status: **Complete**

The first three phases of the project focused on the surface collection pipe network system along the Septima Clark Parkway and throughout the basins, as well as the drop shafts and deep tunnel system which will convey the water to the pump station and outfall that will be installed in the last two phases.

PHASE 4

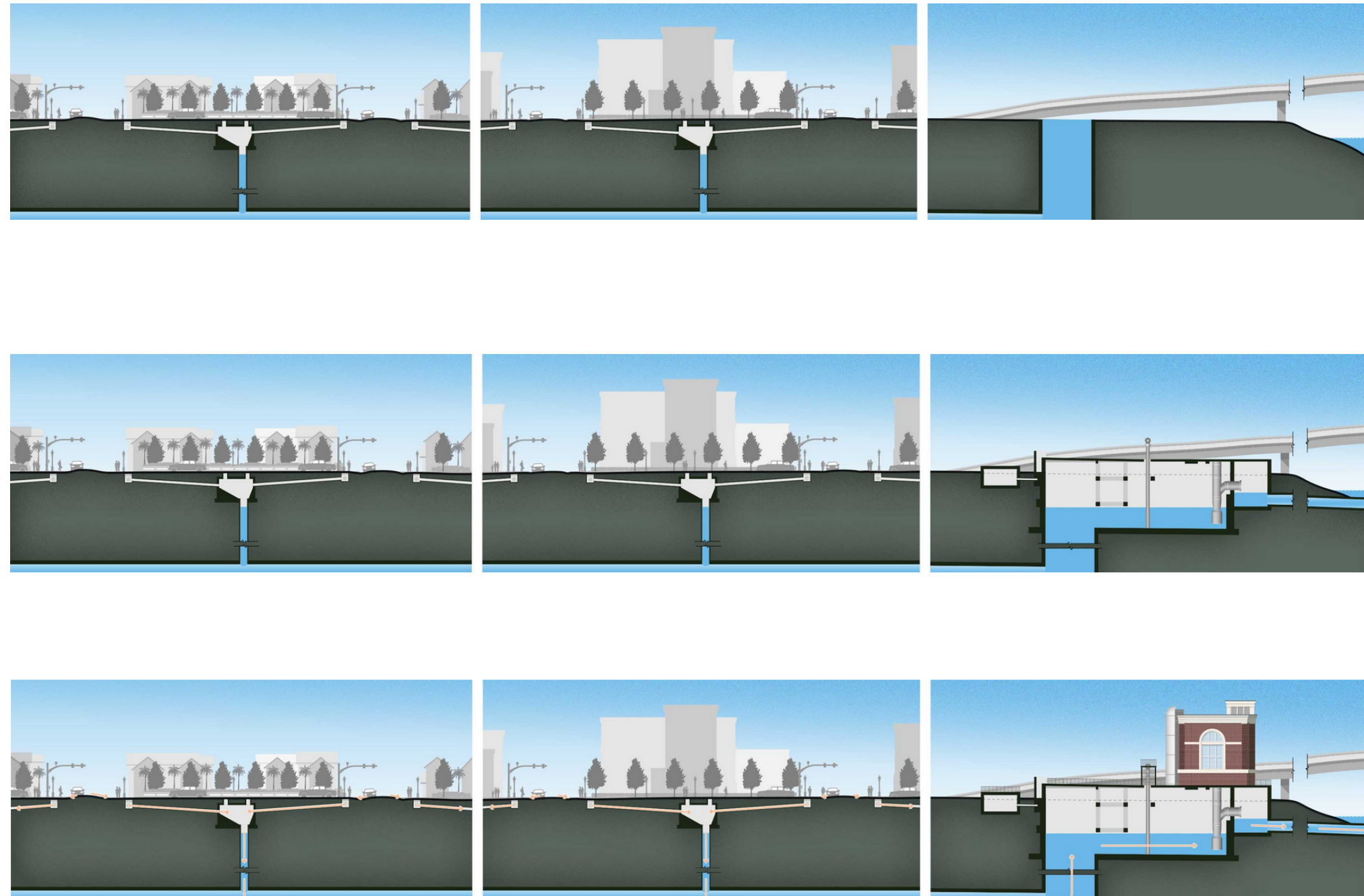
Estimated Completion: **2022**

Phase 4 will consist of the construction of the wetwell and outfall portion of the pump station adjacent to the Ashley River.

PHASE 5

Estimated Completion: **2024**

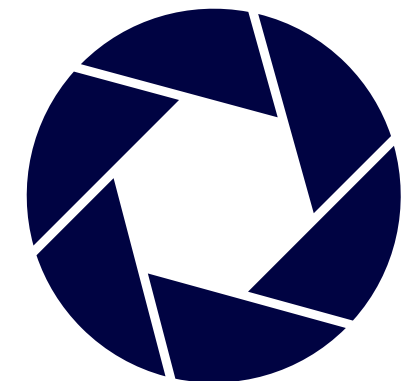
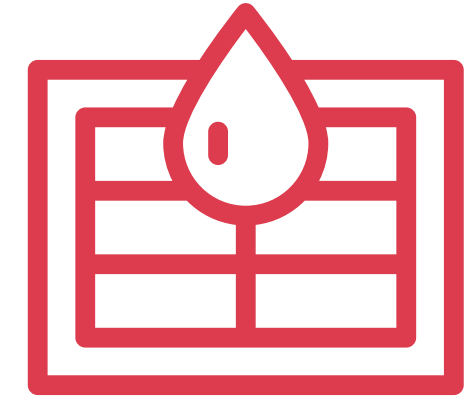
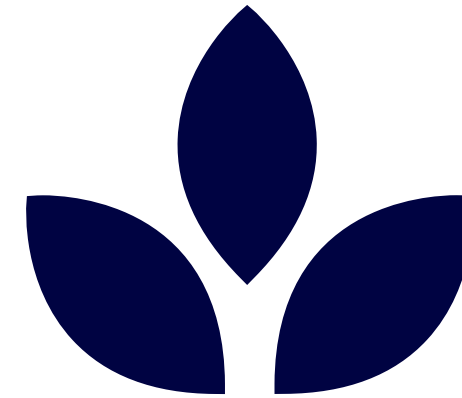
In the final phases, the pump station, which will move water from the deep tunnels to the Ashley River, will be constructed



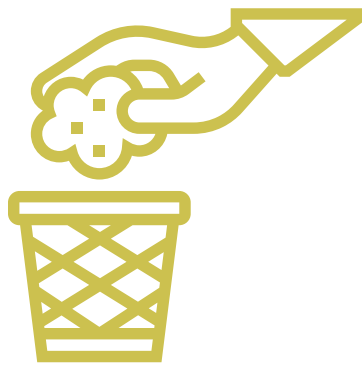
What Residents Can do about the Flooding?

Residents can help themselves by helping the city.

By taking an active role in keeping trash and debris off of the streets and sidewalks as well as out of the storm drain system, the residents of our city would be able to positively affect the stormwater flooding problem tremendously.

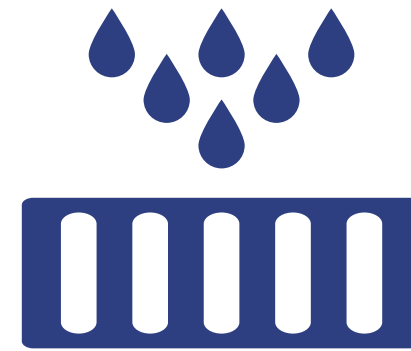


What Residents can do about the Flooding



Stay Responsible

Residents and business owners are accountable for keeping the area in front of their businesses and residences clear of trash



Do Your Part

When a resident notices a clogged drain near their home or business, they are encouraged to try to remove the trash and debris from the drain surface before calling the Stormwater Department, if they feel it is safe to do so.



Keep an Eye on Receptacles

Even if trash has been properly disposed of, trash cans and dumpsters can still pose a hazard to storm drains.

Keep trash cans and dumpsters properly secured to prevent them from floating and overturning.



Ask for Assistance

If a resident has attempted to remove the clog but are unable, or if it is unsafe to do so please call the Citizens Service Desk at (843) 724 - 7311.